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Dated: October 20, 2005 Signature: ____________
(Carol Marstaller)

Docket No.: 47253-00064USPX
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Magnus Bengtsson et al.

Application No.: 10/542671

Confirmation No.: Unknown

Filed: July 18, 2005

Art Unit: N/A

For: TRUNCATION AND LEVEL ADJUSTMENT OF RAKE OUTPUT SYMBOLS

Examiner: Not Yet Assigned

CLAIM FOR PRIORITY

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Applicant hereby claims priority under 35 U.S.C. 119 based on the following prior foreign application filed in the following foreign country on the date indicated:

Country	Application No.	Date
DK	PA 2003 00120	January 30, 2003
EP	03388069.1	October 29, 2003

Dated: October 20, 2005

Respectfully submitted,

By ____________
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Kongeriget Danmark

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Patent application No.: PA 2003 00120

Date of filing: 30 January 2003

Applicant: (Name and address) Telefonaktiebolaget L M Ericsson (publ)
SE-126 25 Stockholm
Sweden

Title: Optimal scaling of RAKE output symbols for WCDMA

IPC: H 04 B 1/707; H 04 B 1/06

This is to certify that the attached documents are exact copies of the above mentioned patent application as originally filed.

Patent- og Varemærkestyrelsen
Økonomi- og Erhvervsministeriet

03 December 2003

HGS

Henrik Grye Skou

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PATENT- OG VAREMÆRKESTYRELSEN

Optimal scaling of RAKE output symbols for WCDMA

Technical Field of the Invention

The invention relates to a method of scaling the RAKE output symbols in a WCDMA receiver. The invention also relates to a corresponding receiver system.

Description of Related Art

In a WCDMA receiver system, see Figure 1, the radio signal is first down converted to base band by the radio interface, not shown in the figure. Then the analog signal is scaled by the automatic gain control (AGC), Block 101, before being quantized by the analog to digital (A/D) converter, Block 102. The signal from the AGC is scaled to keep the average power of the sum of the I and Q parts as close as possible to a given reference value. The measured power could be taken before or after the A/D converter. Usually, some kind of control algorithm is involved in finding the optimal scale factor for the AGC. We assume that such an algorithm is given.

Once the received signal has been quantized it is despread in the RAKE. A radio signal could have travelled through different paths before arriving at the receiver, which causes the signal to be received at different time delays. Given the time of arrival of each path, we despread the received quantized signal in the RAKE, Block 103, for each path. In the RAKE, we multiply the quantized signal, sampled at chip rate, with its corresponding channelization code and scrambling code and sum over the length of the channelization code.

To minimize silicon area, as few bits as possible should be used to represent the output from the truncation and saturation block 104. In Figure 1, we assume that g_I and g_Q are represented with N_g bits. Here, t_I or t_Q is computed from g_I or g_Q by extracting the N_t least significant bits if this still equals g_I or

g_Q. Otherwise, we have overflow and t_I or t_Q is set to the maximum or minimum representable value of t_I or t_Q, which depends on the sign of g_I or g_Q. By saturating the signals t_I or t_Q, we partly solve the problem of overflow. However, if only one of t_I or t_Q saturates, we will loose valuable phase information between g_I or g_Q, see Figure 2. If both t_I and t_Q saturates, we loose even more phase information, since only four phases are possible, see Figure 3. In both cases, we loose valuable soft information, which results in a deteriorated performance. In Block 105 the radio channel estimates are calculated and their conjugates are multiplied with the despread data symbols. The products are then summed over the number of paths. Finally, in Block 106 the bit stream is decoded.

The problem with the current state-of-the-art solution is that we loose valuable soft information if we want the RAKE output to be represented with a small number of bits. The result is a deteriorated performance.

<u>Summary</u>

In the invention, we propose a method to adaptively select the reference power value for the AGC or to scale g_I and g_Q with a reference scale factor before truncation and saturation in Block 204. The reference power level and the reference scale factor depend on the strength of the signal output from the RAKE. In Figure 4, we show an overview of the proposed system. Here Block 207 adjusts either the reference value in the AGC or the truncation and saturation done in Block 204.

With the proposed solution, we adjust the average size of the values output from the RAKE to obtain optimal performance.

<u>Brief Description of the Drawings</u>

The invention will now be described more fully below with reference to the drawings, in which

Figure 1 shows an overview of the receiver,

Figure 2 shows in a dotted box the maximum values of t_I or t_Q. In the figure the coordinate (g_I, g_Q) fall outside the box and will thus be truncated. The result of the truncation and saturation is shown as the coordinate (t_I, t_Q). It is immediately seen that the truncation and saturation introduces a phase error,

Figure 3 shows in a dotted box the maximum values of t_I or t_Q. In the figure both g_I and g_Q fall outside the box and will thus be truncated. The result of the truncation and saturation is shown as the coordinate (t_I, t_Q), which will be located at one of the corners of the box. It is immediately seen that the truncation and saturation introduces a phase error,

Figure 4 shows the proposed modified receiver structure, and

Figure 5 shows a flow diagram of Block 207.

Detailed Description of Embodiments

Let $|x|$ mean the absolute value of x. Let x be a number represented by an integer number of bits N_x. Define M_x and m_x to be the maximum and minimum achievable number using the bit representation of x. Let y be represented with N_y integer bits. Define the truncation of x using saturation as

$$y = sat(x) = \begin{cases} M_y, & x \geq M_y, \\ x, & m_y < x < M_y, \\ m_y, & x \leq m_y. \end{cases}$$

Let the integer part of the number x be represented as $floor(x)$.

Description of Block 207.

In Figure 4, we present the proposed solution. A flow chart of Block 207 is shown in Figure 5. Below, we go through in detail the boxes in Figure 5.

Block 301: Sample the $I_I^{(CH)}$ and $I_Q^{(CH)}$ according to a predetermined pattern for physical channel CH. A given number of physical channels can be studied in parallel. We are interested in if either the I or Q part has saturated. We therefore compute the measurement quantity

$$\Omega^{(CH)} = \max\left(\left|I_I^{(CH)}\right|, \left|I_Q^{(CH)}\right|\right)$$

for each physical channel.

Block 302: Compute the expectation value of $\Omega^{(CH)}$. This can, for example, be done by filtering

$$\Omega_{n+1}^{(CH)} = (1-\alpha)\Omega_n^{(CH)} + \alpha\Omega^{(CH)}.$$

Here, the time constant for α, that is, the time it takes to compute the corresponding moving average, should be much larger than the time constant for the AGC loop. Furthermore, the time constant for α should be large enough to filter over a number of fading peaks and dips.

Block 303: This block is the core of the invention. We present four different methods for computing the reference value.

Algorithm I (Adjusts the reference value for Block 201): Let $\Omega_{ref}^{(CH)}$ be the reference value for $\Omega_n^{(CH)}$. Compute the new reference power value $P_{ref}^{(CH)}$ for the AGC using a PI controller, that is, calculate

$$e_n^{(CH)} = \Omega_{ref}^{(CH)} - \Omega_n^{(CH)},$$

$$I_{n+1}^{(CH)} = I_n^{(CH)} + \frac{1}{T_i} e_n^{(CH)}$$

Here $I_n^{(CH)}$ is stored from the last activation of the block and T_i is an integration constant. Take the new reference power for the AGC for channel CH as

$$P_{ref}^{(CH)} = K(e_n^{(CH)} + I_n^{(CH)})$$

for some constant K.

Usually, we have only one AGC and we set the final reference value as

$$P_{ref} = \min_{CH}(P_{ref}^{(CH)}).$$

Algorithm II (Adjusts the reference value for Block 204): Let $\Omega_{ref}^{(CH)}$ be the reference value for $\Omega_n^{(CH)}$. Compute the new reference scale value for Block 204, $S_{ref}^{(CH)}$, using a PI controller, that is, calculate

$$e_n^{(CH)} = \Omega_{ref}^{(CH)} - \Omega_n^{(CH)},$$

$$I_{n+1}^{(CH)} = I_n^{(CH)} + \frac{1}{T_i} e_n^{(CH)}$$

Here $I_n^{(CH)}$ is stored from the last activation of the block and T_i is an integration constant. Take the new reference scale value for Block 204 for channel CH as

$$S_{ref}^{(CH)} = K(e_n^{(CH)} + I_n^{(CH)})$$

for some constant K.

The truncation and saturation in Block 204 is then done as follows,

$$t_I^{(CH)} = sat(floor(g_I^{(CH)} \cdot S_{ref}^{(CH)})),$$

$$t_Q^{(CH)} = sat(floor(g_Q^{(CH)} \cdot S_{ref}^{(CH)})).$$

In algorithm I and II more general controllers can be used, but for ease of presentation we chose the simple PI controller.

Algorithm III (Adjusts the reference value for Block 201): The following algorithm is a simplified version of algorithm I. We assume that we have two reference power levels, P_1 and P_2. Do the following

$$
\begin{aligned}
&\textbf{if } \Omega_n^{(CH)} > M_{t_I}(1-\gamma_1)\\
&\quad P_{ref}^{(CH)} = P_1\\
&\textbf{elseif } \Omega_n^{(CH)} < M_{t_I}(1-\gamma_2)\\
&\quad P_{ref}^{(CH)} = P_2\\
&\textbf{end}
\end{aligned}
$$

Here, M_{t_I} denotes the maximum value represented by t_I, which is the same for t_Q. This algorithm toggles between two states. Here, $\gamma_1 < \gamma_2$ and $P_1 < P_2$. Having $\gamma_1 < \gamma_2$ introduces a viscosity to the system, which prevents us from toggling between the two reference values P_1 and P_2 from one activation of the block to the other.

Algorithm IV (Adjusts the reference value for Block 204): The following algorithm is a simplified version of algorithm II, similar in style to algorithm II. We assume that we have two reference scale levels, S_1 and S_2. Do the following

$$
\begin{aligned}
&\textbf{if } \Omega_n^{(CH)} > M_{t_I}(1-\gamma_1)\\
&\quad S_{ref}^{(CH)} = S_1\\
&\textbf{elseif } \Omega_n^{(CH)} < M_{t_I}(1-\gamma_2)\\
&\quad S_{ref}^{(CH)} = S_2\\
&\textbf{end}
\end{aligned}
$$

Here, M_{t_I} denotes the maximum value represented by t_I, which is the same for t_Q. This algorithm toggles between two states. Here, $\gamma_1 < \gamma_2$ and $P_1 < P_2$. Having $\gamma_1 < \gamma_2$ introduces a viscosity to the system, which prevents us from toggling between the two reference values P_1 and P_2 from one activation of the block to the other.

The truncation and saturation in Block 204 is then done as follows,

$$t_I^{(CH)} = sat(floor(g_I^{(CH)} \cdot S_{ref}^{(CH)})),$$

$$t_Q^{(CH)} = sat(floor(g_Q^{(CH)} \cdot S_{ref}^{(CH)})).$$

It is straight forward to generalize algorithm III and IV to include more power reference value levels.

Although a preferred embodiment of the present invention has been described and shown, the invention is not restricted to it, but may also be embodied in other ways within the scope of the subject-matter defined in the following claims.

Patent claims:

1. A method of receiving signals in a WCDMA receiver, comprising the steps of:

- converting a received radio signal to an analog base band signal;
- scaling the analog base band signal by an automatic gain control;
- quantizing the scaled analog signal by an analog-to-digital converter;
- despreading the quantized signal in a RAKE unit having a number of fingers, thus providing a number of despread data symbols;
- truncating and saturating the despread data symbols provided from the RAKE unit;
- calculating channel estimates and multiplying the truncated and saturated data symbols by the conjugates of said channel estimates; and
- combining the multiplied data symbols over the number of RAKE fingers to produce estimates of symbols transmitted to the WCDMA receiver,

characterized in that the method further comprises the step of adjusting the level of the despread data symbols provided from the RAKE unit with a reference scale factor depending on the level of the truncated and saturated data symbols.

2. A method according to claim 1, characterized in that the level of the despread data symbols is adjusted by adjusting a reference value of said automatic gain control.

3. A system for receiving WCDMA signals, said system having means for:

- converting a received radio signal to an analog base band signal;
- scaling the analog base band signal by an automatic gain control;
- quantizing the scaled analog signal by an analog-to-digital converter;
- despreading the quantized signal in a RAKE unit having a number of fingers, thus providing a number of despread data symbols;

- truncating and saturating the despread data symbols provided from the RAKE unit;
- calculating channel estimates and multiplying the truncated and saturated data symbols by the conjugates of said channel estimates; and
- combining the multiplied data symbols over the number of RAKE fingers to produce estimates of symbols transmitted to the WCDMA receiver,

c h a r a c t e r i z e d in that the system is further adapted to adjust the level of the despread data symbols provided from the RAKE unit with a reference scale factor depending on the level of the truncated and saturated data symbols.

4. A method according to claim 3, c h a r a c t e r i z e d in that the system is adapted to adjust the level of the despread data symbols by adjusting a reference value of said automatic gain control.

Optimal scaling of RAKE output symbols for WCDMA

ABSTRACT

In a WCDMA receiver, we propose a method to adaptively select the reference power value for the AGC or to scale the despread data symbols provided from the RAKE unit with a reference scale factor before truncation and saturation. The reference power level and the reference scale factor depend on the strength of the signal output from the RAKE. With the proposed solution, we adjust the average size of the values output from the RAKE to obtain optimal performance.

Fig. 4 should be published.

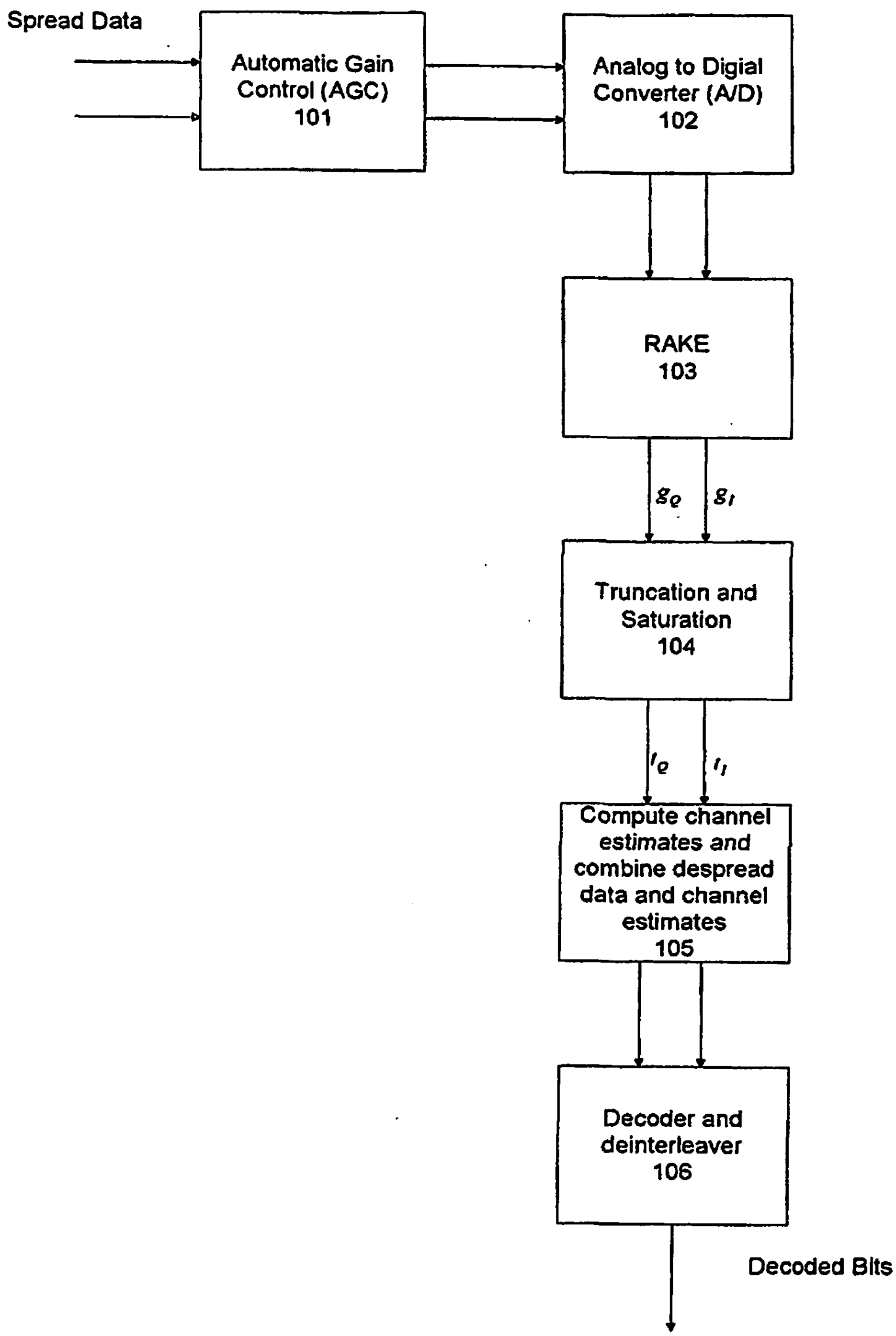
Spread Data
Automatic Gain Control (AGC) 101
Analog to Digial Converter (A/D) 102
RAKE 103
g_Q
g_I
Truncation and Saturation 104
t_Q
t_I
Compute channel estimates and combine despread data and channel estimates 105
Decoder and deinterleaver 106
Decoded Bits

Fig. 1

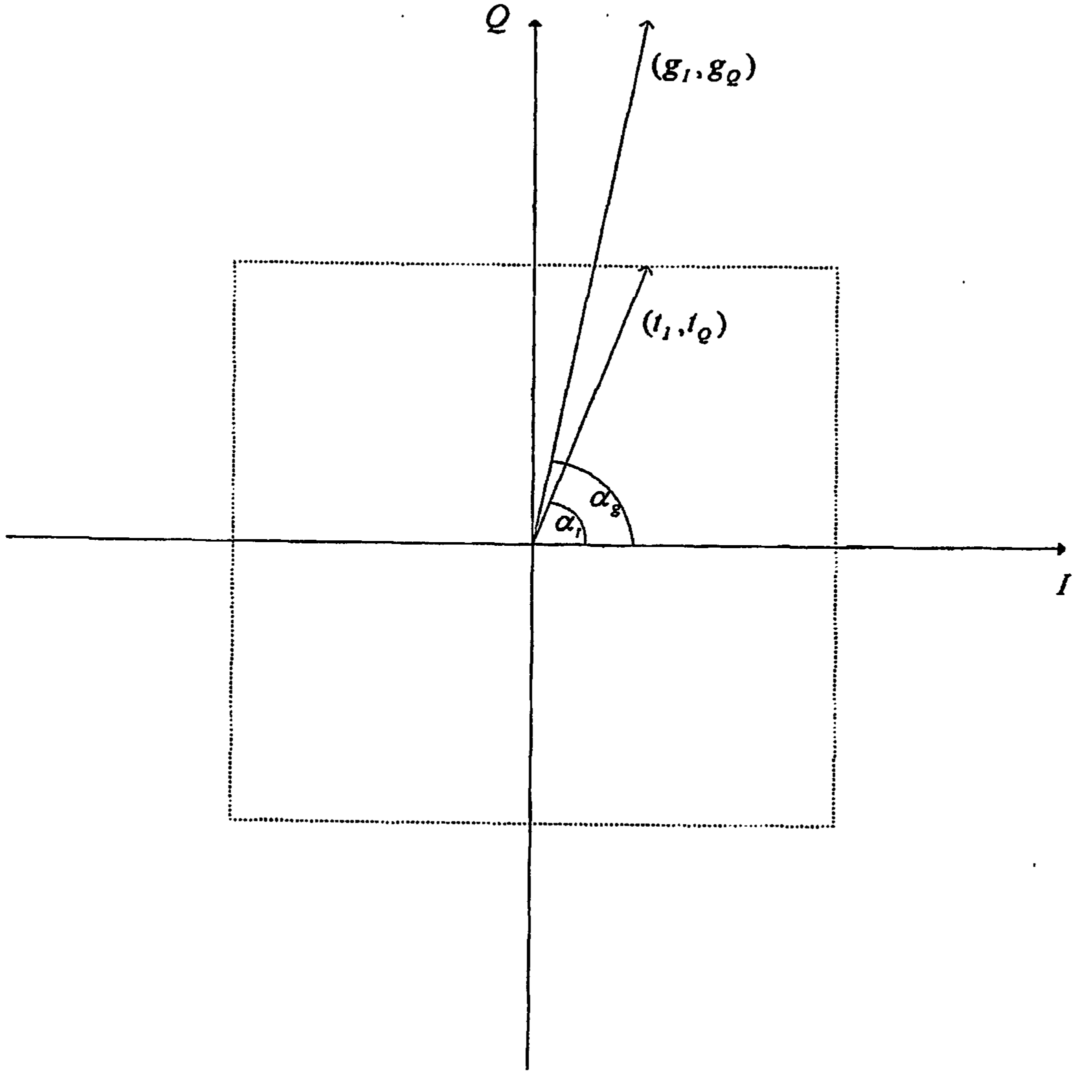

Fig. 2

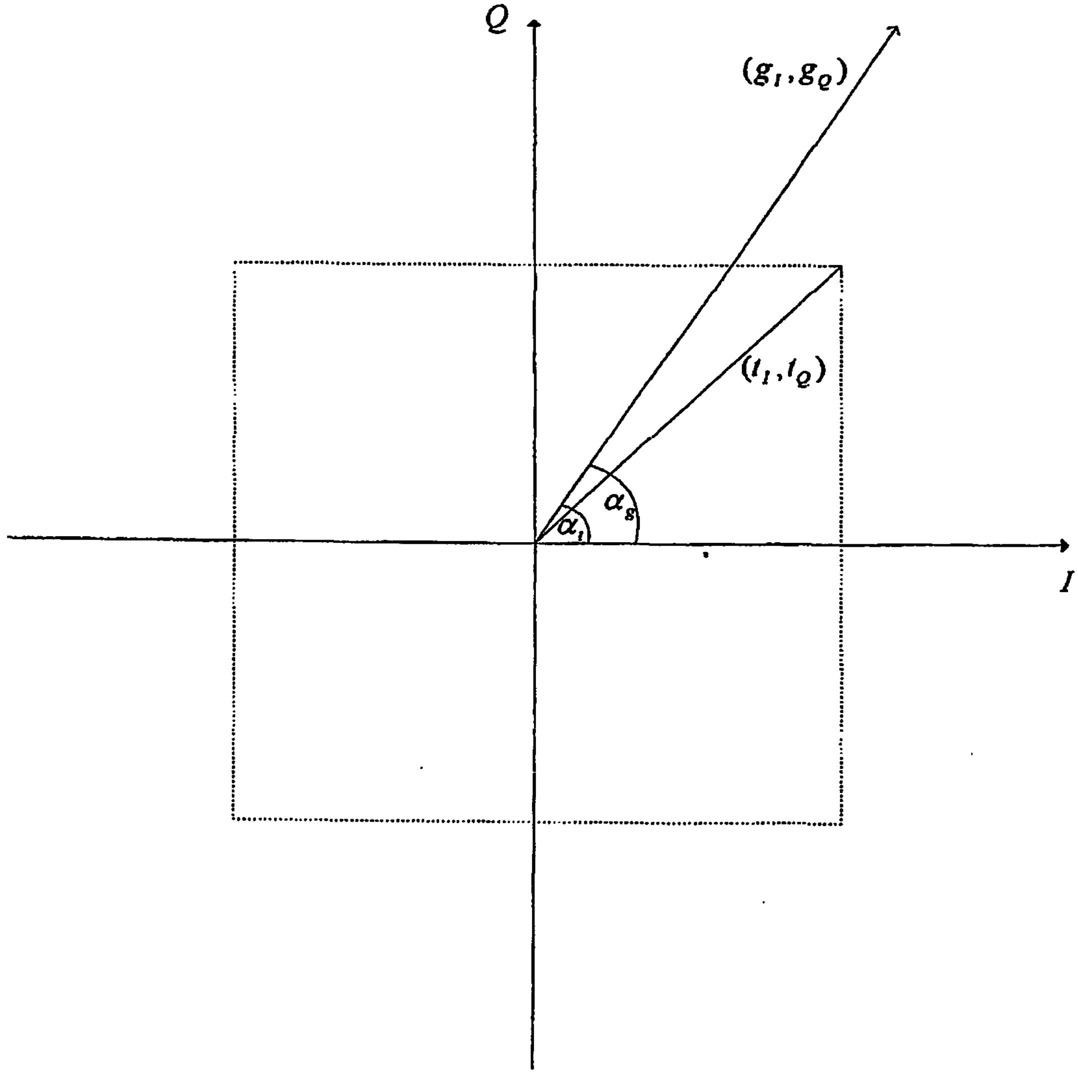

Fig. 3

Modtaget

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PVS

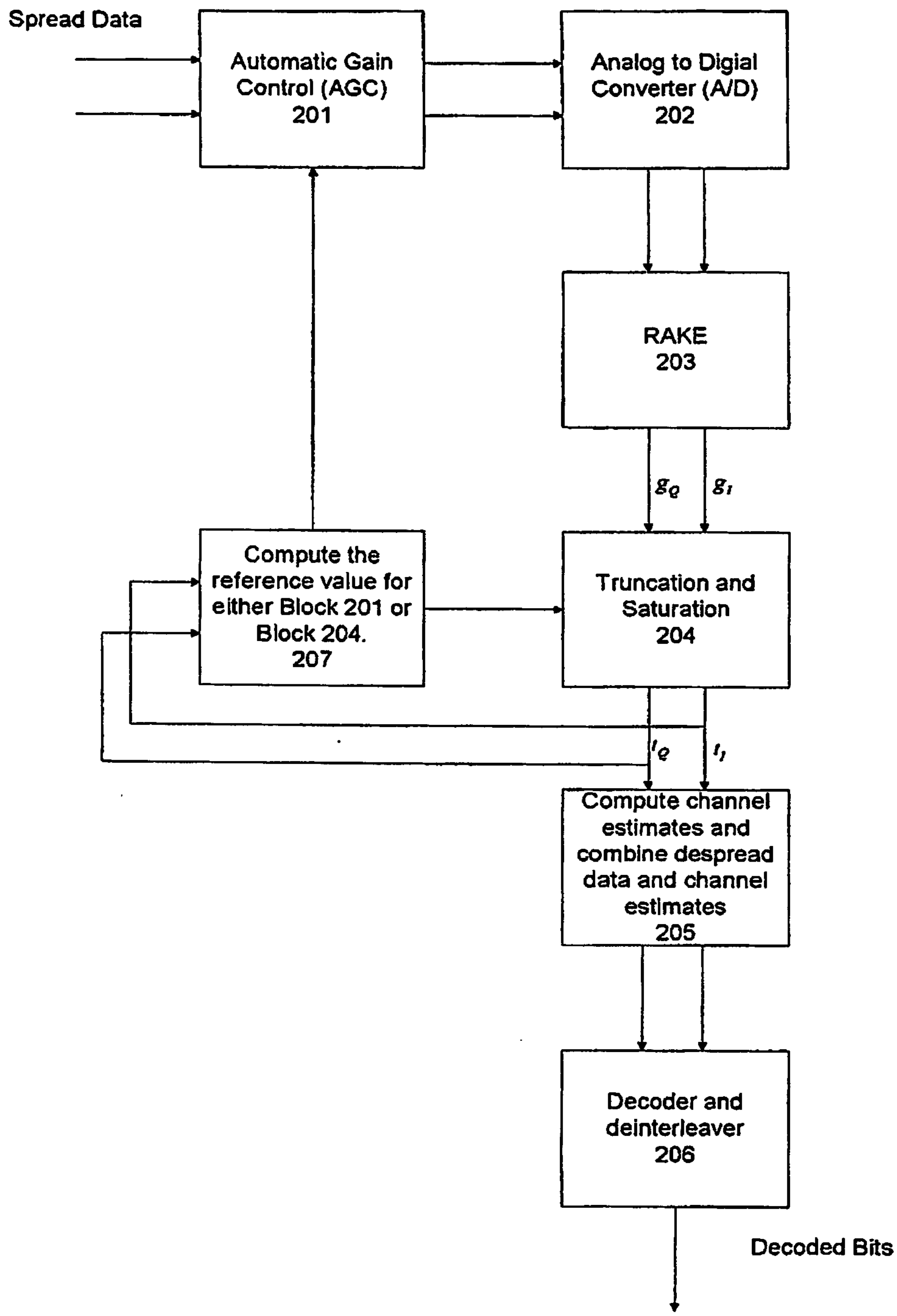

Fig. 4

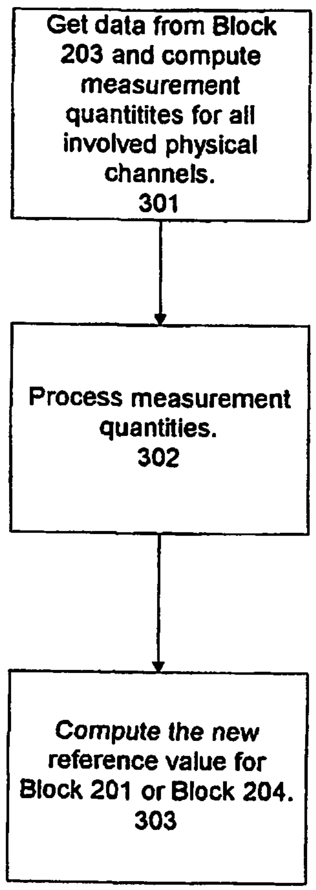
Get data from Block 203 and compute measurement quantitites for all involved physical channels. 301
Process measurement quantities. 302
Compute the new reference value for Block 201 or Block 204. 303

Fig. 5